INVESTIGATIONS ON THE RELATION BETWEEN CESSPOOL NUTRIENTS AND ABUNDANCE OF *HYPNEA MUSCIFORMIS*, WEST MAUI, HAWAII

FINAL REPORT

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EXECUTIVE SUMMARY

Information relating disturbances in coastal marine ecosystems to specific land use activities is critical for development of effective management strategies for pollutant sources. This report is one of a series of investigations on links between land use activities contributing nutrients to shallow coastal waters along the western coastline of Maui and the distribution and abundance of nuisance seaweeds.

On the island of Maui, domestic sewage effluents are discharged underground, either through injection wells on the grounds of municipal sewage treatment plants, or in private cesspools and injection wells located relatively close to the shoreline. Because the shoreline of West Maui has been impacted for nearly ten years by large amounts of the introduced red seaweed *Hypnea musciformis,* considerable attention has been focussed on measuring the relative contributions of nutrients (nitrogen, phosphorus) from natural oceanic waters and from groundwater discharged into the ocean near the coastline to growth of this nuisance seaweed. As groundwater moves seaward, nutrients from several sources on land – namely the high elevation forested lands, agricultural activities at the middle elevations, and resort and residential landscaping activities and sewage disposal near the shoreline – are mixed together and discharged near sea level. It has proved difficult to distinguish the percentage of nutrient loads in groundwater discharged near sea level that originate from each of these land-based sources. The present study tests a new methodology for distinguishing the percentage of nutrients from cesspools (a controllable nutrient source) from all other sources within regions of dense *Hypnea* growth along the coastline of the Lahaina District, West Maui.

Our work shows that a form of the human hormone estrogen, called estrone, is found in high concentrations in domestic sewage relative to oceanic waters, does not change form when diluted with water, and remains dissolved in groundwater rather than binding to the subsurface rock. These findings, based on chemical analyses of sewage and coastal water samples from the Lahaina-Napili Wastewater Reclamation Facility (LNWRF) in West Maui (sewage samples); five locations along the coastline of West Maui; two locations in Maalaea Bay; one location on the south shore of Molokai; and an open ocean station off leeward Oahu, indicate that estrogen compounds are robust, effective and reliable tracers of human sewage effluents as they move from land to the marine environment.

The physical concept is that both the estrone tracer and the dissolved nutrients in groundwater are diluted by the same factor between the source (e.g., cesspool) and the ocean. Measured values of estrone spanned a range of four orders of magnitude (18 to 101,000 picograms (pg)/Liter of water, with the highest concentration in the influent (input) to the LNWRF. We consider this concentration similar to the concentration in domestic waste entering cesspools on Maui. Mean estrone concentrations range from 65 pg/L in the open ocean samples (background value) to 886 pg/L at the Maalaea condominium site. Mean dissolved inorganic nitrogen (DIN) ranged from 0.12 uM (1.68 ug/L) in the open ocean to 130 uM (1820 ug/L; mean salinity 17.4 ppt) at Black Rock; mean dissolved inorganic phosphorus (DIP) ranged from 0.13 uM (4.03 ug/L) in the open

ocean to 2.6 uM (80.6 ug/L; mean salinity 23.5 ppt) at Honokeana. Although the lowest concentrations of nutrients and estrones were measured in the open ocean samples, DIN, DIP and estrone were not significantly correlated across coastal water samples, suggesting that estrone enters the coastal ocean at specific geographic locations, perhaps as a function of variation in cesspool distribution and underground structure along the coast.

The nutrient budgets suggest that the input of nitrogen and phosphorus from cesspools is about the same as the percentage derived using estrone as a tracer. Using the estrone and nutrient data collected during the study and the results of previous studies on *Hypnea* nutrient requirements and nutrient sources, we conclude that the contribution to *Hypnea* growth of nutrients introduced into cesspools is insignificant, estimated at less than one per cent when averaged over the entire coastline of West Maui (35 kilometers) and 3% - 7% for the kilometer of coastline downslope from Wahikuli. The research results also suggest that the contribution of nutrients from shallow injection wells at Maalaea represents a substantial percentage of the nearshore nutrient pool. However, Maalaea was not included within the study boundaries, originally defined as West Maui only; only two samples were collected as a check on the methodology. Additional sampling and analysis at Maalaea is necessary to provide a sufficient body of evidence in support of management actions targeting shallow injection wells.

The body of findings available to date suggest that *Hypnea's* "lifestyle" (e.g., rapid growth rate and ability to settle on high energy rocky shorelines) ideally suits it to exploit the nearshore habitats of West Maui. Considering the total nutrient supply available for algal growth, the open ocean supply is small compared to *Hypnea's* growth requirements, indicating that nutrient input from land is needed for growth of this seaweed. Of the land sources, natural groundwater (i.e., from undeveloped, unfertilized areas) appears to contain about twice the necessary nutrients for seaweed growth. The largest source of groundwater nutrients by far is from large-scale sugarcane (until late 1999) and pineapple agriculture, which contribute about ten times the required nitrogen and three times the required phosphorus to support *Hypnea* growth. Because high levels of nutrients were measured in water samples taken from within dense growths of *Hypnea*, we conclude that nutrients are not the limiting factor for growth.

Evaluating the effect of nutrients from agricultural activities on the nearshore nutrient pool and on *Hypnea* abundance may be possible now that Pioneer Mill has ceased sugar cane cultivation on West Maui. While future land use is still undecided, it is possible that diversified agriculture or housing may in the future occupy former sugar cane fields. If the amount of *Hypnea* along the coastline changes noticeably during the next few years, it would be useful to resample stations downslope of the former sugar cane lands to document the relationship, if any, of changes in land use to changes in nutrient pools, and ultimately, to changes in *Hypnea* abundance. This information would provide important evidence on which to base effective management strategies that may prevent or minimize nuisance seaweed blooms in other areas.